

Portuguese industry and the EU trade emissions directive: development and analysis of CO₂ emission scenarios

C. Borrego*, H. Martins, M. Lopes

Department of Environment and Planning, University of Aveiro, 3810-193 Aveiro, Portugal

Abstract

In December 1997, the Kyoto Protocol was adopted, setting limits on the greenhouse gas (GHG) emissions of industrialized countries. The European Union agreed to reduce its emissions of GHG by 8% during the period 2008–2012 in comparison to their 1990 levels. Subsequently, in a scheme known as “burden-sharing”, Portugal was allowed to increase its emissions by 27% in the same period.

Large industrial facilities are responsible for a significant share of carbon dioxide (CO₂) emissions and are object of a European Directive (2003/87/EC) establishing the scheme for GHG emission allowance trading within the European Union, launched with the purpose of allowing the reduction of GHG emissions cost-effectively. According to the Directive, Member States shall develop a National Allocation Plan (NAP) stating the total quantity of allowances that each one intends to allocate and how it proposes to allocate them among the activities included in the trading scheme.

In this work, an analysis of the Portuguese industry is performed, focused on the energy consumption and CO₂ emissions levels in the period 1990–2001 and on the estimation of the two parameters for the period 2002–2012, considering different economic growth scenarios and investments on energy reduction technologies.

Results show that all the analysed sectors present a significant growth in CO₂ emissions, exceeding the limit established in the frame of the Kyoto Protocol, and that measures other than cost-effective energy technologies will have to be implemented.

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1. Introduction

The Kyoto Protocol was adopted in December 1997 at the third Conference of the Parties to the United Nations Framework Convention on Climate Change, setting limits on the greenhouse gas (GHG) emissions of industrialized countries¹. Under the Protocol, the European Union (EU) agreed to reduce its emissions of GHG by 8% during the period 2008–2012 in comparison to their 1990 levels. Subsequently, on June 1998, this target was reallocated internally, such that differences in the starting point, economic structure and available technologies would be

taken in to account in a scheme known as ‘burden-sharing’. In this context, Portugal was allowed to increase its GHG emissions by 27% in comparison to 1990 levels (Council of the European Union, 1998), which taking into account the six GHG balance corresponds to an increase of 40% in CO₂ emissions (Portuguese Ministry of the Environment, 1997).

The Protocol also introduced three flexible mechanisms essential to its implementation: the international GHG Emissions Trading, the Joint Implementation (JI) and the Clean Development Mechanism (CDM). Emissions’ trading is a scheme whereby companies are allocated allowances for their emissions of GHG, which they can trade subsequently with each other; the total of these allowances allocated to all companies included in the scheme represents the overall limit of emissions allowed by the scheme (COM, 2000). JI and CDM enable the Parties to the Protocol to meet part of their targets by taking advantage of opportunities to reduce

* Corresponding author. Tel.: +351 234 400 800; fax: +351 234 382 876.
E-mail address: borrego@ua.pt (C. Borrego).

¹ The six greenhouse gases covered by the Kyoto Protocol are: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFC), per fluorocarbons (PFC) and sulphur hexafluoride (SF₆).

GHG emissions in other countries at lower cost than at home (more details on these mechanisms can be found in the Appendix).

In July 2003, arising from the need of the EU to reduce its emissions of GHG cost-effectively, the European Council approved a Directive establishing a scheme on GHG emission allowance trading (Directive 2003/87/EC, 2003). The EU trading scheme will come into operation from 1 January 2005 and will initially run for a 3-year period until 31 December 2007. During the first period trading will only include CO₂ emissions from the activities listed in the Directive's Annex I:

- combustion installations (exceeding 20 MW);
- mineral oil refineries and coke ovens;
- production and processing of ferrous metals (including metal ore, pig iron and steel);
- mineral industry (cement clinker, glass and ceramics);
- industrial plants for the production of pulp, paper and board (with production capacity exceeding 20 t per day).

Following this initial 3-year period, the scheme will operate over subsequent 5-year periods. Member states will have the option of including other GHG and additional industrial sectors in the trading scheme, in accordance with the provisions laid down in the Directive. For each of these periods, each member state shall develop a National Allocation Plan (NAP) stating the total quantity of allowances that it intends to allocate for that period and how it proposes to allocate them among the activities included in the trading scheme.

The aim of this paper is to contribute to the understanding of the present situation of the Portuguese transforming industry facing the Kyoto Protocol and the emissions trading Directive. An analysis of the CO₂ emissions from different industry sectors in the 1990–2001 period and the projection for the 2002–2012 period is performed. The projected CO₂ emissions for each sector are analysed in order to verify the accomplishment of the Kyoto Protocol. Furthermore, the CO₂ emission projections are compared with the Portuguese NAP emission allowances (Portuguese Ministry of Economy and Ministry of the Cities, Planning and Environment, 2004).

The industry sectors analysed in this paper are: ceramics, pulp and paper, glass and cement clinker, which correspond to the Portuguese transforming industries included in the Directive's Annex I. These sectors are of great importance in the Portuguese economy and are responsible for 12% of total national CO₂ emissions. Although Annex I from the Directive distinguishes different production capacities in industry installations, that distinction will not be done in this study due to lack of appropriate statistical information. However, this does not constitute a problem since small installations are responsible for less than 10% of the production.

2. Methodology

2.1. CO₂ emissions in the period 1990–2001

The methodology adopted for CO₂ emissions calculation follows the procedures contained in the Directive's Annex IV and the "International Panel for Climate Change" (IPCC) guidelines (IPCC, 1997). According to Annex IV, CO₂ emissions from biomass burning are not accountable, neither indirect emissions from electricity consumption since the Directive refers only to direct emissions. Besides the emissions resulting from the combustion of fossil fuels, the CO₂ emissions resulting from the production process itself will also be taken into account.

The CO₂ emissions (tonnes) resulting from fossil fuels combustion were calculated according to the equation:

$$\text{CO}_2 \text{ emissions (t}_{\text{CO}_2}\text{)} = \text{fossil fuel consumption (TJ)} \\ \times \text{emission factor (t}_{\text{CO}_2} \times \text{TJ}^{-1}\text{)} \\ \times \text{oxidation factor} \quad (1)$$

which was applied separately to each activity sector and each fuel type (TJ is an energy unit equal to 10¹² joules). The data relating to fossil fuel combustion was obtained from the National Energy Accounts, except for the pulp and paper industry where values from the national paper industry association (CELPA) were used since the values from the National Energy Accounts are highly underestimated (CELPA, 2002). The emission factors are those presented in Table 1.

The CO₂ emitted by the production process results from the decomposition of carbonated raw materials and from the consumption of chemical products used as additives. The calculation of these emissions is different for each industry sector:

- Cement industry: CO₂ emissions from the process result from the use of carbonated raw materials and were calculated according to the equation:

$$\text{CO}_2 \text{ emissions (t}_{\text{CO}_2}\text{)} \\ = \text{cement production (t}_{\text{cement}}\text{)} \\ \times \text{emission factor (t}_{\text{CO}_2} \times \text{t}_{\text{cement}}^{-1}\text{)} \quad (2)$$

Table 1
Emission factors (IPCC, 1997).

Fuel	Emission factors (t _{CO₂} TJ ⁻¹)
Anthracite	98.3
Petroleum coke	100.8
LPG	63.1
Gasoline	69.3
Crude oil	73.3
Gas/diesel oil	74.1
Lubricants	73.3
Natural gas	56.1

with the cement production data and the emission factor ($0.446 t_{CO_2}/t_{cement}$) provided by the Portuguese Cement Industry Technical Association.

- Ceramics industry: CO_2 emissions from the process are not significant.
- Glass industry: The main CO_2 emissions from the process result from the use of carbonated raw materials. Due to lack of statistical data on raw material consumption that would allow the use of emission factors, data from one of the main Portuguese glass producers (Barbosa and Almeida, 2002), which indicates a contribution of 30% from the production processes on total glass production CO_2 emissions, was used.
- Pulp and paper industry: The main CO_2 emissions from the process result from the use of chemical products (calcium and sodium carbonate) in the pulp production and were calculated according to the equation:

$$CO_2(t_{CO_2}) = CaCO_3(t) \times \text{emission factor} (t_{CO_2} \times t_{CaCO_3}^{-1}) + Na_2CO_3(t) \times \text{emission factor} (t_{CO_2} \times t_{Na_2CO_3}^{-1}) \quad (3)$$

with the emission factors from the “National Council of the Paper Industry for Air and Stream Improvement” (NCASI, 2002) and chemical products consumption from the Portuguese National Statistics Institute.

2.2. CO_2 emissions projection for the period 2002–2012

In order to estimate CO_2 emissions, the first step was to calculate energy consumption for the period 2002–2012. It took into account the projection of the gross value added (GVA) for Portugal given by the Ministry of Economy (GEPE, 2002), which considered two possible development scenarios:

- Low economic scenario: improvement of the competition capacity through an increase in productivity and a commitment in the binomial price/quality.
- High economic scenario: wide expansion of the industry strategy in the foreign market, through a larger capacity for innovation.

Table 2 presents the GVA projections for each industry sector analysed and for each economic scenario.

With the aim of establishing a baseline energy scenario for energy consumption from the GVA projections, it was assumed that for the period 2002–2012, the value of the energy intensity (i.e., the energy consumption by GVA unit) would be the same as in 2001. The fuel mix of each industry was assumed constant between 2002 and 2012 and equal to that in 2001. For each industry sector, the projection of the base consumption of energy for each year of the period 2002–2012, was calculated according to the equation:

Table 2
GVA average annual growth (%) (GEPE, 2002).

Industry sectors	Low economic scenario (2000–2015)	High economic scenario (2000–2015)
Cement	3.5	2.0
Ceramics	3.7	2.5
Glass	3.5	2.0
Pulp and paper	4.0	3.0

$$\text{Energy consumption}_i \text{ (TJ)} = \text{energy intensity}_{2000} \text{ (TJ } \text{€}^{-1}) \times \text{GVA}_i \text{ (€)} \quad (4)$$

To allow the construction of emission reduction scenarios, a report produced for the European Commission by “AEA Technology Environment” (1999), analysing the industry energetic situation in Portugal, among other EU countries, was used to help estimate the energy consumption reduction potential, and consequently the CO_2 emission reduction potential. In this report, technology cost-supply curves are defined for each of the industry sectors analysed, establishing the priority in terms of options to reduce energy consumption. The technology cost-supply curves illustrate the energy savings potential of different technologies as a function of its specific costs (in monetary units) per unit of energy saved (GJ). Two sets of criteria have been adopted to identify cost effective technologies under:

- normal industrial investment requirements (25% discount rate and 5 year depreciation);
- strategic national investment criteria (4% discount rate and technical lifetime).

The annual cost-effective energy savings for each industry sector, considering the two sets of investment criteria, are presented in Table 3.

Summarising, the present work analyses, for each of the economic scenarios (high and low), three possible energy scenarios:

- baseline energy scenario: calculated through Eq. (4);
- normal investment energy scenario: introduction of energy consumption reduction technologies, considering normal investment criteria;

Table 3
Annual cost-effective energy savings (PJ year⁻¹) (AEA Technology Environment, 1999)

Industry sectors	Normal investment criteria	Strategic investment criteria
Cement	3.1	6.1
Ceramics	1.7	4.3
Glass	6.0	8.2
Pulp and paper	7.0	17.0

- strategic investment energy scenario: introduction of energy consumption reduction technologies, considering strategic investment criteria.

For the normal and strategic investment criteria, the energy consumption estimations were derived from the baseline energy scenario, subtracting the saved energy from total energy.

The CO₂ emissions projection resulting from fossil fuels combustion was estimated according to Eq. (1), using the three energy consumption scenarios estimated.

The CO₂ emissions coming from the production process for the period 2002–2012 were calculated from the CO₂ emissions from the fossil fuels emissions, assuming that the proportion of these emissions in relation to the total CO₂ emissions would remain constant until 2012, in reference to the year 2001.

3. Results and discussion

3.1. Period 1990–2001

Fig. 1 presents the energy consumption for each of the industry sectors studied. It shows the pulp and paper industry as the major energy consumer, with almost 54,000 TJ in 2001. The cement and ceramics industries present similar consumption values, around 37,000 TJ in 2001. Although the glass industry shows energy consumptions significantly smaller, reaching 11,000 TJ in 2001, it presents the greatest growth between 1990 and 2001 (84%). The cement industry was the sector with the smallest energy consumption growth in the same period (37%), while ceramics and the pulp and paper industries present growths of 56 and 67%, respectively.

Since the fuel-mix assumes special importance in the CO₂ emissions quantification, Fig. 2 shows the fuel-mix for 1990, 1995 and 2001. The cement and the glass industries exhibit an important dependence on fossil fuels, while the ceramics and the pulp and paper production present a significant share of biomass as energy source. Regarding the fuel-mix over the analysed period, the cement industry presents a clear substitution of coal by pet-coke, a petrol

derivate; in ceramics, the biomass share decreased from 53% in 1990 to 37% in 2001, due to the fuel shift to natural gas; between 1990 and 1995 the glass industry maintained its fuel mix, while in 2001 natural gas surpassed the petrol derivatives as the main energy source; the fuel mix of the pulp and paper industries has been constant over the years, with biomass as the main energy source and a small contribution of natural gas appearing in 2001.

The fuel mix differences are reflected on the industries' CO₂ emissions, as can be seen in Fig. 3, which presents the total CO₂ emissions for each of the industry sectors studied. The cement industry presents the highest level of CO₂ emissions, with a growth of 31% between 1990 and 2001, reaching near 7000 kt in 2001. The other industry sectors produce much less CO₂: in 2001 the ceramics, glass and the pulp and paper sectors reached 1225, 870 and 871 kt, respectively. The pulp and paper CO₂ emissions have grown 150% between 1990 and 2001, while the ceramics and glass industries present growths of 86 and 51%, respectively.

Fig. 4 shows the share of CO₂ emissions from fossil fuels and from the production process for 2001; in the cement industry, the production process originates almost 60% of the emissions, while in the other industries fossil fuel burning is the main source of CO₂.

3.2. Period 2002–2012

Figs. 5–7 show the energy consumption estimated for 2002–2012, for the baseline energy scenario, the normal investment energy scenario and the strategic investment energy scenario, respectively. For all the scenarios, the pulp and paper industry presents the highest growth in energy consumption with values ranging from 57 to 83 GJ in 2012. The cement and ceramics industries present similar energy consumption levels, around 50 GJ. The glass industry shows the biggest differences between scenarios, reaching in the strategic energy scenario for 2012 values lower than those of 2001.

Table 4 presents the CO₂ emissions estimated for 2002–2012 for the three energy scenarios. The cement industry is clearly the sector with the larger CO₂ emissions, between 7500 and 10,200 kt in 2012, largely due to the high emissions coming from the raw materials processing. The

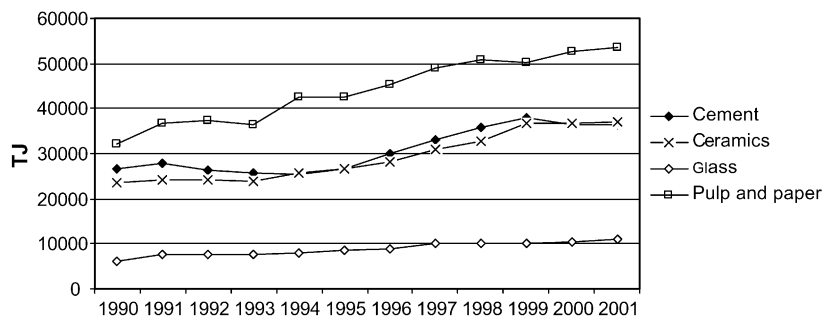


Fig. 1. Energy consumption in the period 1990–2001.

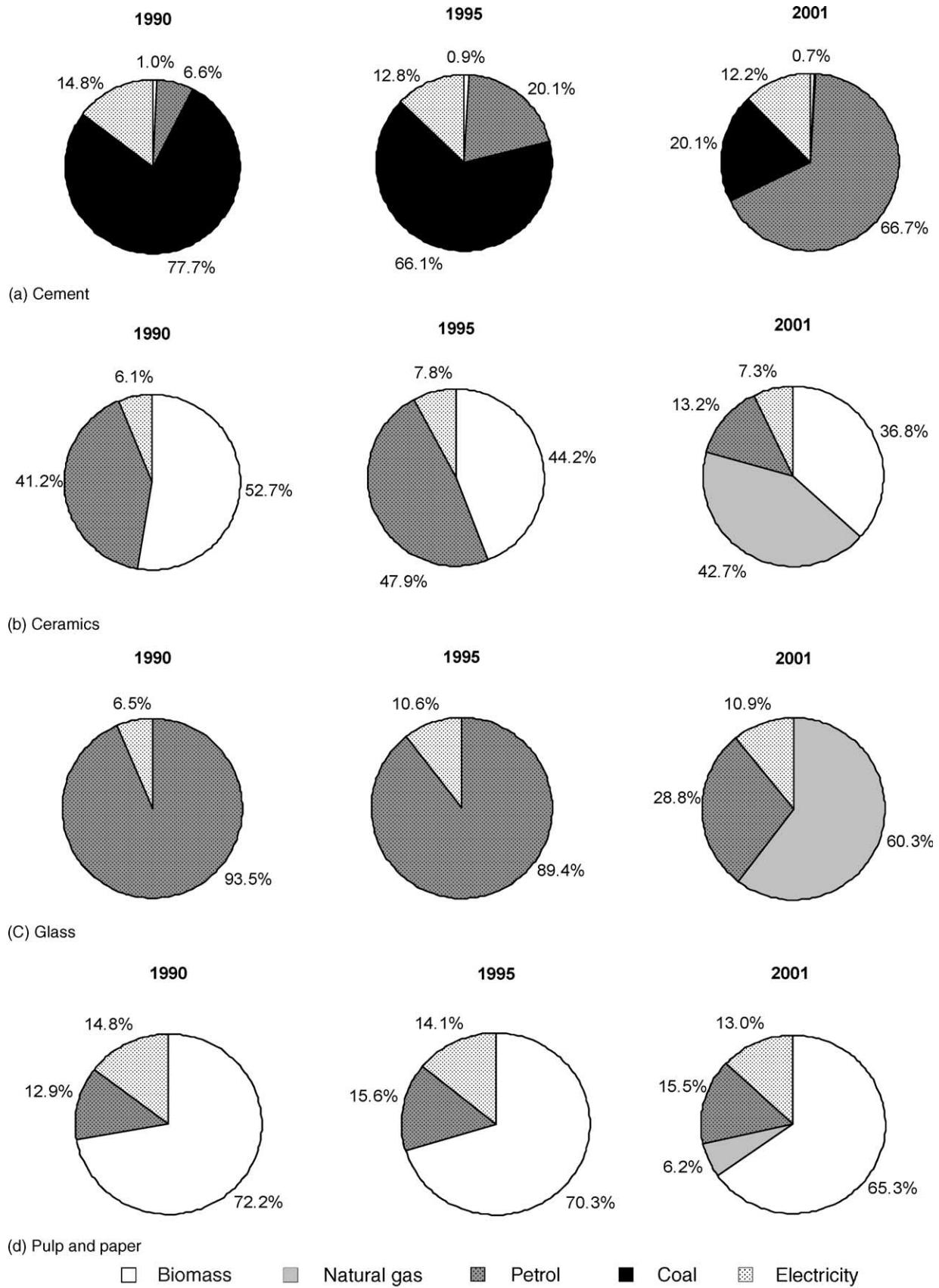


Fig. 2. Fuel-mix for 1990, 1995 and 2001.

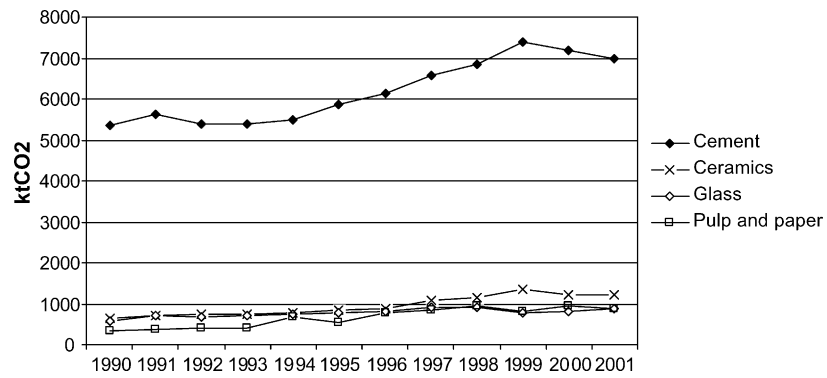
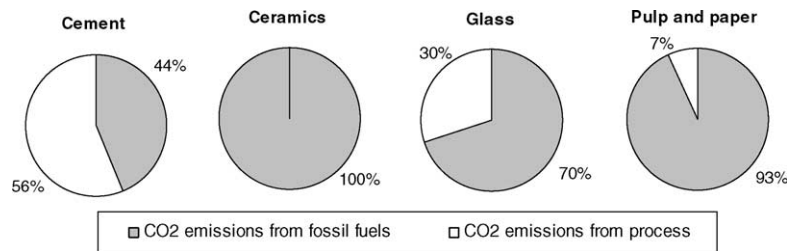
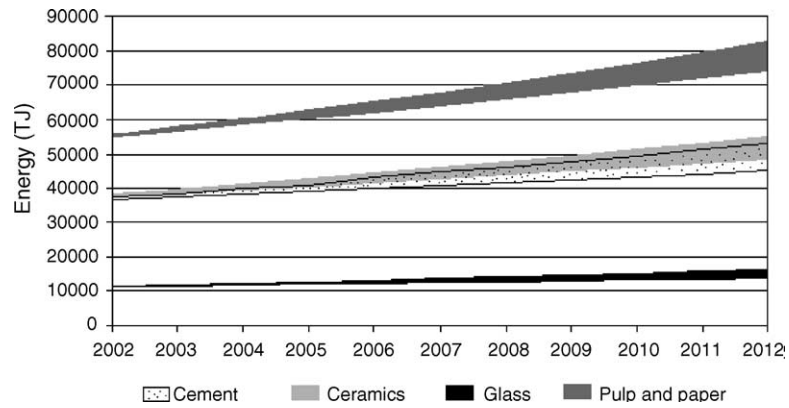
Fig. 3. CO₂ emissions in the period 1990–2001.Fig. 4. CO₂ emissions share for 2001.

Fig. 5. Energy consumption estimation for the base energy scenario.

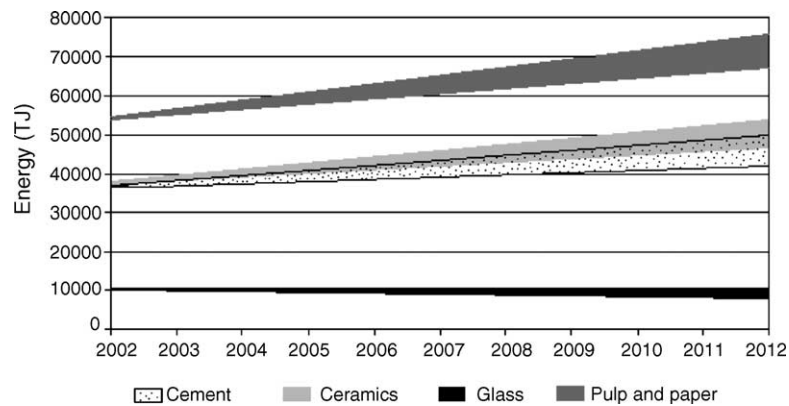


Fig. 6. Energy consumption estimation for the normal investment energy scenario.

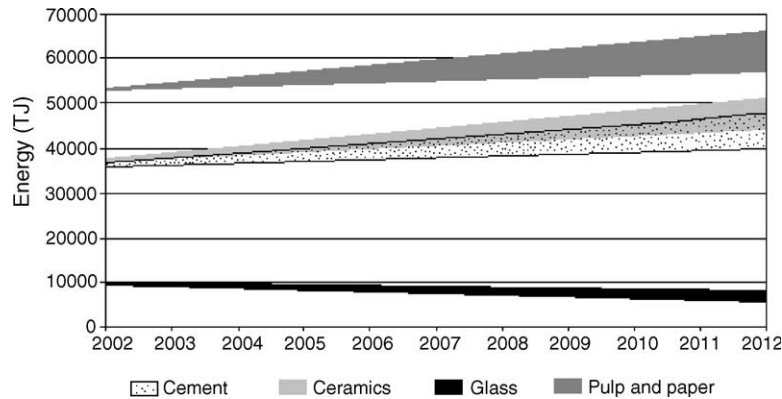


Fig. 7. Energy consumption estimation for the strategic investment energy scenario.

Table 4

CO₂ emissions (kt) estimated for 2002–2012

Industry sectors	Base energy scenario	Normal investment energy scenario	Strategic investment energy scenario
Cement	8690–10204	8094–9608	7517–9266
Ceramics	1607–1827	1551–1770	1465–1684
Glass	1082–1270	611–799	438–627
Pulp and paper	1204–1339	1091–1226	929–1064

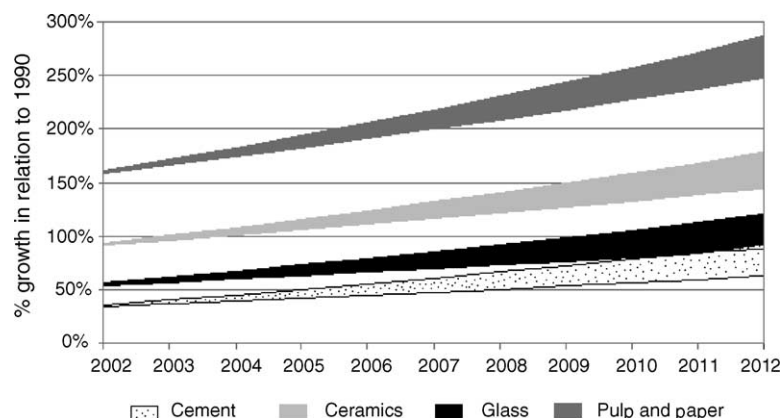
ceramics industry is the second largest emitter with values around 1500 and 1800 kt. Although it is the larger energy consumer, the pulp and paper industry CO₂ emissions are only 12% of the cement industry emissions, since 65% of its energy consumption comes from biomass, a neutral fuel in terms of CO₂. The glass industry presents the lower CO₂ emission levels.

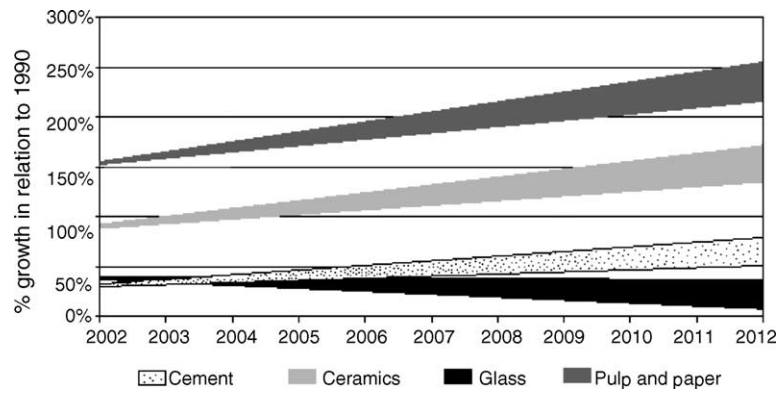
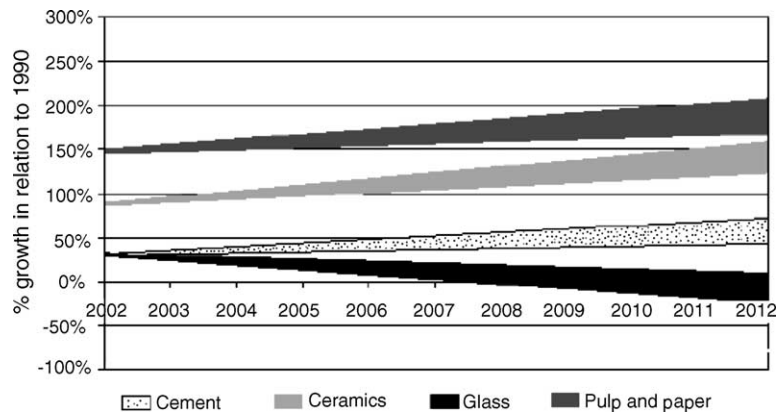
Figs. 8–10 show the CO₂ emissions growth in relation to 1990, estimated for 2002–2012, for each of the studied sectors. Fig. 8 shows that for the baseline energy scenario, i.e. without any energy efficient technology introduction, none of the industry sectors will be able to fulfil the 40% limit growth. It is also possible to observe that the pulp and paper industry presents the highest CO₂ growth (between 250 and 290%), while the cement industry presents the lowest growth (between 60 and 90%). Figs. 9 and 10 show that the glass industry presents the largest CO₂ reduction

potential, being the only sector to grow below 40%, and even emit less CO₂ in 2012 in relation to 1990, in the strategic scenario. The pulp and paper industry also presents, in the strategic energy scenario, an interesting CO₂ reduction potential but not sufficient to grow below 170%. The cement and ceramics industry present low CO₂ reduction potentials, with minimum growths of 41 and 123%, respectively.

3.3. The portuguese national allocation plan

In accordance with the Directive on GHG emission trading, Portugal submitted in May 2004 the NAP (Portuguese Ministry of Economy and Ministry of the Cities, Planning and Environment, 2004) to the European Commission. The reference scenario from the Portuguese National Climate Change Programme (PNAC, 2002) was assumed to determine the total quantity of allowances to

Fig. 8. CO₂ emission growth estimation for the base energy scenario.

Fig. 9. CO₂ emission growth estimation for the normal investment energy scenario.Fig. 10. CO₂ emission growth estimation for the strategic investment energy scenario.

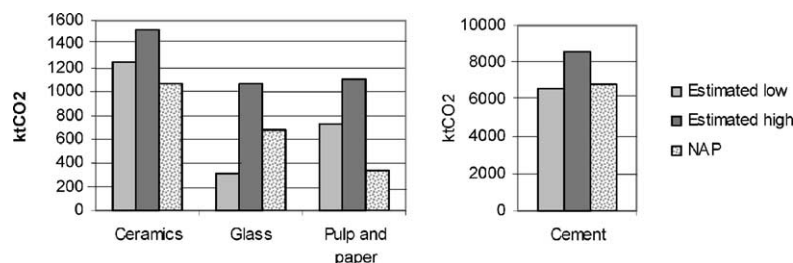
allocate to sectors covered by the Directive. The allocation of allowances by activity sector was based on the sum of historical emissions from installations or, in specific cases, on projections. The amount of allowances to allocate to each sector resulted from the sum of emissions calculated for each installation in the sector, multiplied by a global adjustment factor, allowing the accommodation of a marginal increase in capacity used by existing installations. The base criterion for emissions calculation per installation was the result, as a maximum value, of the average of the 2 years of higher emissions from the 3-year periods of 2000–2002 or 2001–2003.

In November 2003, the Portuguese Industry Confederation (CIP) released a document stating its position in relation

to the Kyoto Protocol and the EU emission trade scheme (CIP, 2003). CIP states that in order to guarantee that the application of the Directive will not affect economic convergence and the industries sustainability in a significant way, the NAP should attribute around 38 Mt CO₂ per year emissions free of licence charge for the period 2005–2007, necessary to cover the predicted emissions.

The proposed NAP met the CIP expectations allocating 116.6 Mt CO₂ allowances (38.9 Mt CO₂ year⁻¹), free of charge, for the period 2005–2007 to the sectors covered by the Directive.

Fig. 11 presents a comparison between the CO₂ projections and the Portuguese NAP CO₂ allowance proposal for the industry sectors under study. The values

Fig. 11. Comparison between CO₂ projections and the Portuguese NAP CO₂ allowance proposal.

are similar except for CO₂ emissions from the pulp and paper industry. This fact can be explained due the fact that the projections and the NAP calculations are based on different energy consumption data sources: the National Paper Industry (CELPA, 2002) and the National Energy Accounts, respectively.

4. Conclusions

All the sectors present in a “business as usual” scenario, a significant growth in energy consumption and, consequently, in CO₂ emissions in the period 1990–2012. In fact, between 1990 and 2001, CO₂ emissions have grown above the 40% limit in all industry sectors (86, 51 and 150% for ceramics, glass and pulp and paper, respectively) except for cement (31% growth). This increase compromised greatly the estimations for 2012, even in the most favourable slow-growing economy with a strategic energy scenario.

The glass sector presents itself as the only sector able to grow below the 40% limit until 2012, due to its significant energy reduction potential. In the context of the emission trading mechanism, the glass industry appears as a future CO₂ emission allowance seller, provided the investment in energy efficient technologies.

The pulp and paper industry appears in a very unfavourable position; despite presenting the greatest cost-effective energy savings and a major contribution of biomass in its fuel mix, in the most favourable scenario the CO₂ emissions will grow 170%, in part due to the enormous growth that occurred in the 1990–2001 period.

The cement and ceramics industries present small energy consumption reduction potential, meaning that almost all the cost-effective energy saving technologies have already been implemented. In these two sectors, measures other than energy efficient technologies will have to be implemented to reduce CO₂ emission growth such as fuel switching and, in the particular case of the cement industry, the production of cement with lower clinker content. Cement production assumes a special importance since its CO₂ emission levels are five to eight times bigger than the other sectors.

In the framework of the market mechanisms established by the Kyoto Protocol, these three sectors (cement, ceramics and pulp and paper), as potential CO₂ emission allowance buyers, should consider alternative strategies such as JI and CDM. In fact, the Portuguese Industry Confederation (CIP) defends in its position paper that these mechanisms are essential to cover the emission deficit estimated for 2008–2012 (CIP, 2003). CIP considers that, following the example from other EU countries, a “Carbon Fund” should be established allowing the country to cover the emission deficit in the most economic efficient way. The process would take place through direct investment in JI/CDM projects, which the Fund would finance. This fund would serve as an external policy instrument promoting also the sustainable development in developing countries.

The industry considers that the “Carbon Fund” should be financed by the national government since they consider that during the EU “burden-sharing” negotiations “Portugal agreed on a highly ambitious and unrealistic objective” (CIP, 2003). Portugal negotiated the lowest CO₂ emissions per capita in the EU (7.6 tCO₂eq), significantly below the EU average objective (10 tCO₂eq) and also because sectors outside the Directive will grow more than 100% during the 1990–2012 period, creating difficulties for Portugal under the Kyoto Protocol.

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Appendix A.

A.1. *Kyoto's market-based flexible mechanisms*

The Kyoto Protocol envisages three market-based “flexible mechanisms”: Emissions Trading, Joint Implementation (JI) and Clean Development Mechanisms (CDM). These will to allow industrialised countries to meet their targets through trading emission allowances between themselves and gaining credits for emission-curbing projects abroad.

The rationale behind these three mechanisms is that GHG are a global problem and that the place where reductions are achieved is of less importance. In this way, reductions can be made where costs are lowest, at least in the initial phase of combating climate change.

A.2. *Emissions trading*

While the implementation of the three flexible mechanisms at international level will become possible only once the Kyoto Protocol comes into force, the EU is moving ahead with its own internal emissions trading system. The EU scheme will be the first multi-national emissions trading scheme in the world and is considered a forerunner of the international emissions trading scheme under the Kyoto Protocol.

Under the EU emissions trading scheme, the EU Member States will set limits on CO₂ emissions from energy-intensive industries by issuing allowances as to how much CO₂ these industries are allowed to emit. Industries that achieve reductions can sell them to companies that have problems staying within their limits or for which emissions

reduction measures are too expensive in comparison with what the allowances will cost. Any industry may also increase its emissions above the level of allowance it is issued by acquiring more allowances from the market. This scheme will induce companies to make emission cuts where they are cheapest, thereby ensuring that reductions are made at the lowest possible cost to the economy and also that innovation is fostered.

The EU has also indicated its willingness to link the EU scheme to trading schemes in other countries that have ratified the Kyoto protocol.

A.3. Joint implementation and the clean development mechanism

Under the Kyoto Protocol, Joint Implementation (JI) and the Clean Development Mechanism (CDM) will allow industrialised countries to achieve part of their emission reduction commitments by conducting emission-reducing projects abroad and counting the reductions achieved toward their own commitments. JI will allow for projects in other industrialised countries with Kyoto targets, while CDM will take place in countries without targets, i.e. developing countries. A condition for the issue of credits in respect of the reductions achieved is that the projects result in real, measurable and long-term climate change benefits.

Building on these provisions and the EU emissions trading system, the Commission adopted on July 2003 a proposal that links credits from JI and CDM projects with the emissions trading system. Under this proposal, European industries covered by the EU emissions trading system will be allowed to convert credits from JI and CDM projects for use towards meeting their commitments under the trading system. Governments will also be allowed to use credits from JI and CDM projects towards meeting their commitments under the Kyoto Protocol during the first commitment period 2008–2012, provided that the Protocol enters into force.

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- Carlos Borrego** is professor of environmental engineering, with focus on Air Pollution and Energy and Environment. He has the habilitation on applied environmental sciences from the University of Aveiro, PhD and MSc from the Free University of Brussels and a degree in mechanical engineering from the Technical University of Lisbon. Currently, he is the scientific co-ordinator of five projects under sixth FP of EC Environment and Sustainable Development Programme and four projects under the National Funding Agency. He is also Chairman of the Scientific Board of International Technical Meetings of NATO-CCMS on Air Pollution Modelling and its Application and was vice-chairman of the Environmental Assessment Group of EUROTRAC-2 (EUREKA Environmental Project), from 1997 to 2000.
- Helena Martins** is a PhD student in sciences applied to the environment at the University of Aveiro. She has a master of science degree on economics and politics of energy and environment and a degree on environmental engineering. Currently, she is part of the Research Group on Emissions, Modelling and Climate Change (GEMAC). Her research interests include air pollution (emissions and modelling), environmental economics, climate change and urban air quality.
- Myriam Lopes** is invited assistant at Department of Environment and Planning at the University of Aveiro. She is an environmental engineer and has a master of science degree on air pollution. Currently, she is finishing her PhD on climate change and the use of economic instruments to mitigate greenhouse gases emissions in Portugal, working in the Research Group on Emissions, Modelling and Climate Change (GEMAC). Her research interests include environmental politics, atmospheric and energy modelling, environmental economics and pollution health effects.